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PATENT ABSTRACTS OF JAPAN

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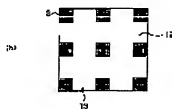
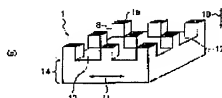
(72)Inventor : NAKAMURA HIROFUMI
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(54) PIEZOELECTRIC ACTUATOR AND FABRICATION THEREOF

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a compact piezoelectric actuator, and a fabrication method thereof, in which piezoelectric elements are formed at high positional accuracy and high integration density through a simplified fabrication process.

SOLUTION: A pie-zoelectric material green sheet applied with a plurality of common electrodes, a piezoelectric material green sheet applied with a plurality of signal applying electrodes, and a sheet applied with no electrode are employed. A group of alternate laminate composed of a plurality of sheets applied with common electrode and a plurality of sheets applied with signal applying electrode and a group of laminate composed of a plurality of sheets applied with no inner electrode are laminated alternately and fired. Subsequently, grid-like trenches 12, 13 are made in the displacement output face side to form checkered driving posts 8 thus realizing a compact piezoelectric actuator having high positional accuracy and high integration density. The common electrode and the signal applying electrode can be connected electrically with an external power supply on the back plane 1r of the output plane for each driving post.



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(54)【発明の名称】圧電アクチュエータおよびその製造方法

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(57)【特許請求の範囲】

【請求項1】 基板と、該基板上にアレイ状に配列されており、夫々が圧電振効果によって圧電式駆動機構として機能する複数の駆動柱と、前記駆動柱の夫々に対応して配設される外部共通電極及び外部信号印加電極とを備え、

前記各駆動柱は、少なくとも該駆動柱下部の基板部分と共通のグリーンシートによって一体に形成されたブロックから成り、該ブロックは、前記外部共通電極に共通に接続された共通電極層を有し圧電材料から成る複数のグリーンシートと、前記外部信号印加電極に接続された信号印加電極層を有し圧電材料から成る複数のグリーンシートとが交互に積層された積層体構造に形成され、前記共通電極層及び信号印加電極層の夫々が、各駆動柱内に収容される駆動柱電極部と、該駆動柱電極部と前記

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外部共通電極又は外部信号印加電極との間を接続する電極取出し部とから構成され、前記共通電極又は信号印加電極のそれぞれの電極取出し部は積層方向に重ならない位置で配設され、前記外部共通電極及び前記外部信号印加電極が、前記基板の下面に配設されていることを特徴とする圧電アクチュエータ。

【請求項2】 前記共通電極層及び前記信号印加電極層の各縁部が、前記各駆動柱の側面に露出する、請求項1に記載の圧電アクチュエータ。

10 【請求項3】 前記共通電極層及び前記信号印加電極層の各縁部が、前記各駆動柱の側面で覆われる、請求項1に記載の圧電アクチュエータ。

【請求項4】 前記駆動柱と実質的に同じ形状の複数のダミー柱を前記基板上に有する、請求項1～3の何れかに記載の圧電アクチュエータ。

【請求項5】 前記駆動柱及び前記基板が平行四辺形であり、前記駆動柱は前記基板の各辺に平行に配列される、請求項1～4の何れかに記載の圧電アクチュエータ。

【請求項6】 前記基板は、前記ブロックの間に挿入される別のブロックを含み、該別のブロックは圧電材料から成るグリーンシートの積層体として構成される、請求項1～5の何れかに記載の圧電アクチュエータ。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】 本発明は、圧電アクチュエータおよびその製造方法に関し、更に詳しくは、特にインクジェット方式記録装置に最適で、高い位置精度、高集積密度で形成され、安定して駆動させることが可能な圧電アクチュエータおよびその製造方法に関するものである。

【0002】

【従来の技術】 インクジェット式のプリンタ（以下、インクジェット記録装置と言う）では、インクを噴射するインクジェットヘッドに、圧電アクチュエータが用いられていることが多量。インクジェットヘッドに用いる従来の圧電アクチュエータは、例えば特開平8-156272号に記載されている。以下、特開平8-156272号を引用し、図面を参照して、従来の圧電アクチュエータを説明する。図12(a)及び(b)は、それぞれ、従来の圧電アクチュエータを製造する工程毎の斜視図である。従来の圧電アクチュエータ36を製造するには、まず、基板14上に形成した電極用パタン26、27に沿って、積層型の圧電素子プレート28を接合する（図12(a)参照）。次いで、圧電素子プレート28と基板14の表面部とに、圧電素子プレート28の長手方向と直交する所定ピッチのスリット加電を施して、複数の積層型圧電素子（駆動柱）29、30となる圧電素子列31を形成し、電極用パタン26、27を各積層型圧電素子29に対応する個別電極（信号印加電極）33に分断する（図12(b)参照）。

【0003】 各圧電素子列31の圧電素子29、30の両端面には、内部電極を1層おきに相互接続した端面電極（外部電極）を設ける。一方の端面の外部電極を基板14上の内部電極である共通電極32に、他方の端面電極を基板14上の内部電極である個別電極33に、それぞれ導電性材料を介して接続する。更に、基板14上の圧電素子29、30の両面に、上面高さが圧電素子29、30とほぼ同一になる支持部材34を接合する。積層型圧電素子29、30は、変位出力面を基板と反対側の上面部に有し、圧電駆動効果によって積層方向と同一方向の変位を出力する。

【0004】

【発明が解決しようとする課題】 ところで、従来技術では、圧電素子プレートに長手方向と直交する方向のスリ

ットを加工することにより複数の圧電素子を形成するため、各圧電素子の平面形状は長方形であり、それに対応して上方に配されるインク室やインク吐出用のノズルも同様の配置となる。また、圧電駆動効果を利用して圧電素子を駆動させているため、圧電素子プレートの端面電極と電極パタンとを導電性材料によって接続する行程が必要となる。更に、基板上の圧電素子プレート長手方向と直交する方向の両端部には、各圧電素子列に対応する電極パタンとして個別電極を形成する。このため、1つのアクチュエータユニット上に圧電素子列を2列を超えて、言い換えると2列よりも多く設けることは困難であり、従って、単位面積あたりのノズル数を高めることができず、しかも、生産性が低いという第1の問題があった。また、基板と圧電素子との材質が異なるため、スリットを加工する際、互いの熱膨張係数や加工性の差が生じる第2の問題があった。更に、圧電素子プレート及び支持部材を基板に接合させる際、何れも接合する行程が必要であり、また、圧電素子プレートを接合する際に基板上の電極パタンに位置合わせしたとき、各圧電素子プレート間の相対的な位置がずれるという第3の問題もあった。以上のような事情に照らして、本発明の目的は、圧電素子が簡略化された製造工程で高い位置精度及び高集積密度で形成された、コンパクトな圧電アクチュエータ及びその製造方法を提供することである。

【0005】

【課題を解決するための手段】 本発明者は、鋭意検討の結果、変位出力面が圧電駆動効果を利用して変位する圧電アクチュエータを考え、圧電素子を縦横両方向に略等間隔な碁盤目状又は千鳥状に平面配置することで、圧電素子を高集積に配置できることを見出し、本発明者は本発明を完成するに至った。

【0006】 上記目的を達成するために、本発明の圧電アクチュエータは、基板と、該基板上にアレイ状に配列されており、夫々が圧電駆動効果によって圧電式駆動機構として機能する複数個の駆動柱と、前記駆動柱の夫々に対応して配設される外部共通電極及び外部信号印加電極とを備え、前記各駆動柱は、少なくとも該駆動柱下部の基板部分と共通のグリーンシートによって一体に形成されたブロックから成り、該ブロックは、前記外部共通電極に共通に接続された共通電極層を有し圧電材料から成る複数枚のグリーンシートと、前記外部信号印加電極に接続された信号印加電極層を有し圧電材料から成る複数枚のグリーンシートとが交互に積層された積層体構造に形成されることを特徴とする。

【0007】 本発明の圧電アクチュエータによれば、駆動柱と基板とを共通のグリーンシートによって一体に形成したことにより、駆動柱の位置精度の向上が可能となり、また、製造する際の工程数が削減できる。ここで、前記外部共通電極及び前記外部信号印加電極は、前記基板の下面に配設することが出来る。また、前記共通電極

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層及び前記信号印加電極層の各縁部が、前記各駆動柱の側面に露出することも、前記各駆動柱の側面に覆われるとすることも出来る。

【0008】前記共通電極層及び信号印加電極層の夫々を、各駆動柱内に収容される駆動柱電極部と、該駆動柱電極部と前記外部電極との間を接続する電極取出し部とから構成することが好ましい。この場合、外部電極との接続が容易である。また、前記駆動柱と実質的に同じ形状の複数のダミー柱を前記基板下に有することも本発明の好ましい態様である。或いは、前記駆動柱及び前記基

【0009】外部共通電極及び外部信号印加電極は、一般に外部電源に接続される。例えば、内部電極である共通電極層及び信号印加電極層は、通常、駆動柱を構成する駆動柱部と、駆動柱部に接続し、裏面にまで到達する電極取り出し部とから構成され、共通電極層及び信号印加電極層の形状は、駆動柱部では同一形状で、かつ積層方向について同一位置に配置され、電極取り出し部では、積層方向について互いに重ならないように配置される。従って、各駆動柱毎に、共通電極の電極取り出し部、及び、信号印加電極の電極取り出し部の端部を裏面にそれぞれ配列して露出させ、各外部電極に容易に接続できる。また、グリーンシートの表面に電極ペーストを塗布して外部電極を形成するにあたり、電極層の駆動柱部が駆動柱の内部に収まるように予め形成してもよい。そして、駆動柱を形成する際、内部電極が駆動柱内に収まるように格子状の溝を加工することで、耐久性に優れた圧電アクチュエータが製作される。

【0010】駆動柱に加えて電極層を有しないダミー柱を形成すると、駆動柱を個別に駆動させて、駆動する駆動柱（以下、駆動駆動柱と言う）の隣の駆動柱を駆動させないときに、駆動させない駆動柱が変位することを大きく抑制でき、駆動駆動柱の出力変位を有効利用できる。

【0011】本発明の圧電アクチュエータは、好適には、インクジェットヘッド用の圧電アクチュエータとして利用される。この場合、各駆動柱はインクジェットヘッドのインクノズルからインクを流出させる駆動機構として機能する。これにより、高密度に印字可能なインクジェット記録装置用の圧電アクチュエータを実現できる。

【0012】また、本発明の圧電アクチュエータの製造方法は：圧電材料から成り、共通電極層を有する複数の第1のグリーンシートを形成するステップ；圧電材料から成り、信号印加電極層を有する複数の第2のグリーン

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シートを形成するステップ；圧電材料から成る少なくとも1つの第3のグリーンシートを形成するステップ；夫々が第1のグリーンシート及び第2のグリーンシートを交互に含む複数の第1のブロックと、複数の第3のグリーンシートから成る少なくとも1つの第2のブロックとを交互に積層して積層体を形成するステップ；前記積層体の積層方向に延びる第1の溝と、前記積層方向に直交する方向に延びる第2の溝とを積層体の表面に形成して、アレイ状に配設された複数の駆動柱を形成するステップ；及び、前記各駆動柱の共通電極層を共通に接続する外部共通電極及び前記各駆動柱の信号印加電極層を接続する外部信号印加電極を、前記各駆動柱に対応して形成するステップを有することを特徴とする。

【0013】本発明方法によれば、前記本発明の圧電アクチュエータを生産性高く製造できる。積層体を形成する際には、プレス等により加圧を行い、また、焼結を利用することが好ましい。焼結としては、例えば焼成を行う。その際、圧電材料グリーンシートがバインダを含む場合、脱バインダ工程を行う。また、加工は、通常、研削により行う。溝は、格子状などの概略等ピッチに形成される。溝の形成により、著望目状に平面配置された高集積密度の駆動柱を形成できる。また、基板を平行四辺形とし、溝を平行四辺形の辺に沿って形成してもよい。平行四辺形の隣接する辺の成す角度は、例えば45°〜90°程度とする。

【0014】
【発明の実施の形態】以下に、実施形態例を挙げ、添付図面を参照して、本発明の実施の形態を具体的にかつより詳細に説明する。

30 実施形態例1

本実施形態例は、第1発明の実施形態例である。図1(a)から(c)は、それぞれ、本実施形態例の圧電アクチュエータの斜視図、平面図、及び、背面図である。

【0015】本実施形態例の圧電アクチュエータ1は、それぞれ、格子状の溝により区分された各区域に配置され、かつ、圧電式駆動機構として機能する複数の駆動柱8を備えている。図2は、圧電材料グリーンシートとその上に塗布した内部電極である共通電極のボタンを示す平面図、図3は、圧電材料グリーンシートとその上に塗布した内部電極である信号印加電極のボタンを示す平面図である。駆動柱8は、圧電材料グリーンシートを介して溝の幅方向に交互に積層された共通電極2及び信号印加電極3の積層電極構造からなり、圧電効果により駆動柱高さ方向の外部に変位出力する変位出力面（圧電アクチュエータ出力面）1aを駆動柱上端面に有する。共通電極2及び信号印加電極3は、何れも、駆動柱を構成する駆動柱部6と、駆動柱部6に接続し、圧電アクチュエータ1の裏面1r（図1(c)参照）にまで到達する電極取り出し部7とから構成される。また、共通電極2及び信号印加電極3は、駆動柱部6が積層方向に

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て同一位置で、また、電極取り出し部7が被層方向について互いに重ならない位置にそれぞれ配置されるように設けられている。裏面1rでは、各駆動柱毎に、共通電極の電極取り出し部、及び、信号印加電極の電極取り出し部の端部が、それぞれ一列に配列して露出している(図1(c)参照)。

【0016】本実施形態例では、各シートに塗布する共通電極2及び信号印加電極3はそれぞれ3つであるが、駆動柱8の所要数に応じて更に多くしてもよい。また、圧電材料グリーンシート(以下、単にグリーンシートと言う)として圧電材料であるジルコン酸チタン酸鉛セラミックスと有機バインダからなるものを用いたが、圧電材料としては一般的な強誘電体等を用いてもよい。また、グリーンシートはドクターブレード法を用いて製作し、厚さは30 μ m程度としたが、圧電アクチュエータ1の所望の変位量に応じた厚さとすることが可能である。

【0017】以下、圧電アクチュエータの製造方法を説明する。まず、共通電極2を塗布したシート4と信号印加電極3を塗布したシート5とを、それぞれの電極パターンの駆動柱部6が互いに重なるように、かつ、電極取り出し部7が共通電極2と信号印加電極3とで互いに重ならないように、交互に積層した(以下、この積層したものを「駆動柱部を含む層群」と言う)。駆動柱部を含む層群は20層からなる。また、電極を塗布しないシートを別途に複数枚積層した(以下、この積層したものを「駆動柱部を含まない層群」と言う)。駆動柱部を含まない層群も20層からなる。尚、グリーンシート上の共通電極2及び信号印加電極3は、銀パラジウムペーストを塗布(スクリーン印刷)することにより形成したが、その他の導体金属を用いて蒸着等により形成してもよい。

【0018】次いで、駆動柱部を含む層群1cと駆動柱部を含まない層群1dとを更に交互に積層し、駆動柱部を含む層群1cを3体、駆動柱部を含まない層群1dを2体有する積層体1eを形成した。図4(a)及び(b)は、それぞれ、積層体1eの斜視図及び平面図である。図4で破線は、内蔵されている共通電極2及び信号印加電極3の外枠を示す。尚、図4(a)では、層群のため、駆動柱部を含む層群1cのうち最も手前のものにのみ破線を描いている。交互に積層した結果、図4(a)及び(b)に示すように、駆動柱8を形成する部分が、内部電極2、3の列設方向11すなわち各グリーンシートに平行な方向に、及び、列設方向11に直交する方向に、それぞれ3列に配列された。尚、駆動柱8の所望の配列に応じて、さらに多くの層群を積層することも可能である。

【0019】次いで、熱プレス等によって上記の積層体1eを圧着、一体化した。積層体1eの内部には多量の有機バインダが含まれているため、更に、脱バインダ行

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投を行い、続いて1100℃で焼成を行った。次いで、焼成後の積層体に、ダイシングソーにより圧電アクチュエータのユニットとしての所望の寸法に切断した。その際、各駆動柱8を分離、独立させるための溝加工時に積層体を位置決めする必要があることを考慮し、共通電極2及び信号印加電極3の端部が変位出力面1aに露出するように加工した。さらに、積層体の裏面側から、電極取り出し部7の端部が露出するような外形加工を行い、各駆動柱8に電圧を印加する端子を裏面1rに形成した。

【0020】続いて、以下に説明するように、ダイシングソーによって溝加工を行って、駆動柱部6を有する駆動柱8を形成した。まず、列設方向11で駆動柱部を含む層群間に、駆動柱部を含まない層群1dと同一の幅を有する複数本の溝12を形成した。溝12は、深さ1mmの切り込みを上面から入れることにより形成した。続いて、溝12と直交する内部電極積層層方向に、駆動柱部同士間の間隔と同一幅を有する溝13を加工し、複数本の駆動柱8を形成した(図1(a)及び(b)参照)。

【0021】以上の行程により、駆動柱8が圧電アクチュエータ1と同材料でか一つ体で構成され、駆動柱8がマトリクス状に平面配置された圧電アクチュエータが製作された。尚、溝12及び13の幅は何れも、0.718mm、駆動柱8の縦幅の幅は何れも0.3mmであり、また、内部電極2、3の列設方向11及びそれに直交する方向の各駆動柱ピッチは何れも1.018mmであるが、これらの値は、駆動柱の所望ピッチ等に応じて変更することができる。

【0022】次いで、各駆動柱8に印加電圧を加えるための外部電極接続を以下のようにして行った。裏面1rでは、各駆動柱8に対応した共通電極2の取り出し部断面15と信号印加電極3の取り出し部断面16とがそれぞれ露出しており、これらに接ペースト(図示せず)を塗布して外部電極を形成した。更に、外部電極に、各駆動柱8の共通電極2と信号印加電極3の間に選択的に垂直印加することの可能なボタンを有するFPCケーブル(図示せず)を接続した。この結果、各駆動柱8を個別に駆動することができ、なお、外部電極は、上記の方法に代えて、導体金属の蒸着や導体ペーストの印刷などを行って形成してもよい。

【0023】以下、本実施形態例で製作した圧電アクチュエータ1の動作について説明する。裏面1rに接続したFPCケーブルを介して、各駆動柱8の共通電極2と信号印加電極3との間に電圧を印加する。これにより、電極取り出し部7を介して共通電極2の駆動柱部6と信号印加電極3の駆動柱部6との間に電位差が生じ、圧電効果によって、変位出力面1aに、垂直方向10の変位が出力される。

【0024】尚、圧電アクチュエータ1が、共通電極2及び信号印加電極3に代えて、圧電材料グリーンシート

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を介して着の深さ方向に交互に積層された共通電極及び信号印加電極を備え、圧電縦効果により駆動柱高さ方向の外部に変位出力する変位出力面（圧電アクチュエータ出力面）を駆動柱上端面に有する構造であっても、本実施形態例と同様、コンパクトであって各駆動柱毎に変位させることが可能である。

【0025】圧電アクチュエータの動作確認を行った実施例1

圧電アクチュエータ1に接続されたFPCケーブルに、図10に示すような波形の電圧を印加した結果、最大、 $3\mu\text{m}$ 程度の変位を出力できた。その他の駆動柱に対しても同様の駆動実験を行った結果、すべての駆動柱で同等の出力変位特性が得られた。さらに、図11に示すように、ノズル21、圧室22、インク流路23、振動板24を有するインクジェットヘッドに圧電アクチュエータ1を組み込むことにより取付けた。次いで、図10に示した波形の電圧を印加してインク滴の吐出評価試験を行った結果、すべてのノズル21からインク滴が安定して吐出できることを確認した。

【0026】実施形態例2

本実施形態例は、第2発明の圧電アクチュエータ及びその製造方法の実施形態例である。図5は、本実施形態例の圧電アクチュエータの平面図である。本実施形態例の圧電アクチュエータ40は、縦横に直交するマトリクス状に平面配置されている実施形態例1の圧電アクチュエータ1に比べ、駆動柱が千鳥状に平面配置されていることを除いて、圧電アクチュエータ1と同じ構成である。圧電アクチュエータ40の駆動柱42は、それぞれ、交差角度 $\theta = 85^\circ$ で互いに交差する略格子状の溝により区分された各区画に千鳥状に配置され、かつ、圧電式駆動機構として機能する。

【0027】本実施形態例で圧電アクチュエータ40を製作するには、実施形態例1で使用したシート4及びシート5を用い、実施形態例1に比べ、駆動柱部を含む層群と駆動柱部を含まない層群とを交互に積層する際、駆動柱部を含む層群1cが利設方向11に同一所定長さだけ順次移動した状態にして積層した。所定長さとは、交差角度 θ に対応する長さである。その後、実施形態例1と同様、脱パインダ行程、焼成及び外形加工を行った。

【0028】続いて、ダイシングソーによって、以下に説明する溝加工を行い、上面に露出した内部電極（共通電極2及び信号印加電極3）の駆動柱部6を含む駆動柱42を形成した。まず、実施形態例1と同様に溝12を形成した。次いで、溝12と 85° で交差する溝43を形成した。以上の行程により、駆動柱42が、圧電アクチュエータ40と一体でかつ同じ材料で構成され、しかも千鳥状に平面配置された圧電アクチュエータ40が製作された。

【0029】圧電アクチュエータの動作確認を行った実施例2

実験例1と同様の駆動実験を行った結果、すべての駆動柱が $0.3\mu\text{m}$ 程度の変位を出力することを確認した。さらに、本実施形態例で製作したアクチュエータを図11に示したインクジェットヘッドに組み込んで吐出評価試験を行ったところ、全てのノズル21からインク滴を安定して吐出できた。

【0030】実施形態例3

本実施形態例は、外部電源の内部電極への電気接続を、アクチュエータ出力面の裏面1rではなく変位出力面1aで行うことが可能な圧電アクチュエータ及びその製造方法の実施形態例である。図6（a）及び（b）は、何れも本実施形態例の圧電アクチュエータ44の内部電極ボタンを示す側面断面図であり、図6（a）は共通電極ボタンを示し、図6（b）は信号印加電極ボタンを示す。圧電アクチュエータ44は駆動柱48を備えている。駆動柱48は、互いに向向する側面46a、bにそれぞれ共通電極2及び信号印加電極3の端部が露出していることを除いて、駆動柱8と同じ構成で同じ位置に設けられている。

【0031】圧電アクチュエータ44を製作するには、実施形態例1又は2で、グリーンシート上に共通電極2、信号印加電極3を塗布する代わりに、駆動柱部47a、bをそれぞれ有する共通電極及び信号印加電極を塗布（スクリーン印刷）することにより形成した。その後、実施形態例1又は2と同様、積層体を形成し、外形加工及び溝加工を行うことと、相互に向向する側面46a、bに、それぞれ、共通電極の駆動柱部47a及び信号印加電極の駆動柱部47bの端部がそれぞれ露出した駆動柱48を形成した。更に、側面46a、bに外部電極として銀ペースト（図示せず）を全面に塗布し、続いて、外部電源から電圧を印加する電気配線をこの外部電極に接続した。

【0032】本実施形態例の圧電アクチュエータ44は、実施形態例1及び2のように、駆動柱部6からアクチュエータ出力面の裏面1rへ接続する電極取り出し部7を形成しなくてもよいので、内部電極材や圧電材料の使用量を低減でき、製造コストの低い圧電アクチュエータが実現される。

【0033】実施形態例4

図7は、本実施形態例の圧電アクチュエータの斜視図である。本実施形態例の圧電アクチュエータ50は、格子状の溝加工によって積層体上部に駆動柱のみが形成される実施形態例1の圧電アクチュエータに比べ、駆動柱間にも、駆動柱と概略同一寸法で、積層された圧電材料グリーンシートのみからなる支持柱52をグリニャー柱として有する。支持柱52は、内部電極である共通電極2及び信号印加電極3を有さず、積層された圧電材料グリーンシートのみから構成される。

【0034】圧電アクチュエータ50の製造方法を以下に説明する。本実施形態例では、まず、実施形態例1と

同様にして積層体1eを形成した。次いで、駆動柱8及び支持柱52を形成する溝であって、列設方向11に平行で、駆動柱部を含む層群1cと駆動柱部を含まない層群1dとの間に形成された溝56を加工した。続いて、溝56に直交する方向で駆動柱8と支持柱52との間に溝58を加工した。本実施形態例では、駆動柱8及び支持柱52の幅を0.3mm、溝56、58の幅を0.209mm、駆動柱8のピッチを内部電極の列設方向11及び列設方向に直交する方向にそれぞれ、0.018mmとしたが、これらの値は、駆動柱の所望ピッチ等に応じて変更することができる。

【0035】圧電アクチュエータの動作確認を行った実験例3

本実施形態例により製造された圧電アクチュエータ50を実験例1と同様、インジェクションヘッドとして適用し、支持柱52がある場合と無い場合とのインク滴の吐出について比較する実験を行った。その結果、支持柱52を更に備えたことにより他の部位の変形が抑制され、駆動柱8の出力変位を有効利用でき、クロストーク現象の度合いを低減できた。すなわち、吐出に要する出力変位を軽減でき、また、各ノズルの吐出特性のばらつきが軽減することが確認された。

【0036】実施形態例5

本実施形態例は、実施形態例1に比べ、内部電極の駆動柱部が露出しない構造の圧電アクチュエータの実施形態例である。図8(a)及び(b)は、何れも本実施形態例の圧電アクチュエータ60の内部電極ボタンを示す側面断面図であり、図8(a)は共通電極ボタンを示し、図8(b)は信号印加電極ボタンを示す。圧電アクチュエータ60は、内部電極である共通電極及び信号印加電極が、圧電アクチュエータ60の駆動柱62に内蔵されている圧電材料グリーンシート材によって表面が覆われていることを除いて、実施形態例1の圧電アクチュエータ1と同じである。

【0037】圧電アクチュエータ60を製造するには、溝を加工する際、内部電極の駆動柱部66の端部が駆動柱62の外側に露出しないように加工することを含めて、実施形態例1と同じである。

【0038】本実施形態例では、グリーンシート上に内部電極を塗布する工程で、駆動柱部66を駆動柱62の内部に収まるように形成し、内部電極が駆動柱62の外側に露出しないため、各電極層間の短絡を抑制できる効果がある。

【0039】圧電アクチュエータの性能確認を行った実験例

圧電アクチュエータ60を用い、内部電極の駆動柱部66が露出した場合と露出しない場合の耐久性能を比較する実験を行った。その結果、駆動柱部66を露出させないことによって耐久性を向上させることが確認された。

【0040】実施形態例5の改変例

実施形態例5では、格子状又は略格子状の溝の深さは、図8に示したように、内部電極の駆動柱部66の下端に合わせて加工したが、本改変例の第1圧電アクチュエータ(図示せず)は、格子状の溝を駆動柱部66の下端よりも相対的に深く形成してなる圧電アクチュエータである。第1圧電アクチュエータでは、溝底エッジ部周辺での応力集中が緩和され、圧電アクチュエータ60の耐久性を更に向上できる効果が得られた。また、本改変例の第2圧電アクチュエータ(図示せず)は、駆動柱部66の下端位置が格子状溝の底より深い圧電アクチュエータである。第2圧電アクチュエータでは、同一高さの駆動柱と比較して出力変位を向上できる効果が得られた。更に、実施形態例5では、駆動柱を縦横3×3の9個を平面配置する構成としたが、所望の配列に応じ、1枚のシートに電極ボタン数を増加したり、駆動柱部を含む層群と駆動柱部を含まない層群との層積数を増加したりすることにより、圧電アクチュエータ60に比べて更に多くの駆動柱62を有する圧電アクチュエータを形成することができた。尚、本改変例と同様の効果が実施形態例1から4でも得られることを確認した。

【0041】変形例型6

図9(a)及び(b)は、何れも本実施形態例の圧電アクチュエータの内部電極ボタンを示す側面断面図であり、図9(a)は共通電極ボタンを示し、図9(b)は信号印加電極ボタンを示す。本実施形態例の圧電アクチュエータ70は、内部電極が、電極取り出し部76a、bを電極取り出し部72に代えて有することを除いて、実施形態例5の圧電アクチュエータ60と同じ構成である。電極取り出し部76a、bは、圧電アクチュエータ70の駆動柱72の対向する側面74a、bに端部を露出している。本実施形態例では、圧電アクチュエータ70を製造した後、側面74a、bに露出した内部電極端部に銀ペーストを塗布してなる外部電極78a、bを形成した。本実施形態例により、実施形態例5と同様の効果を実することができる。

【0042】

【発明の効果】以上説明したように、本発明の第1発明に係る圧電アクチュエータによれば、それぞれ、格子状の溝により区分された各区域に配置され、かつ、格子状駆動機構として機能する複数の駆動柱を備え、圧電効果により駆動柱高さ方向の外部に変位出力する。これにより、複数の駆動柱を圧電アクチュエータと同じ材質で、かつ圧電アクチュエータと一体に設けることができるので、駆動柱の位置精度の向上及び製造工程の削減が可能となる。また、駆動柱をマトリクス状に平面配置でき、かつ駆動柱を構成する内部電極の電気的な接続部をアクチュエータ裏面で行えるため、駆動柱が高集積密度で配線されたコンパクトな圧電アクチュエータが実現される。第2、第3発明でも同様の効果を実することができる。好適には、駆動柱間に、駆動柱と同様同一高さ

で、積層された圧電材料グリーンシートのみからなるダミー柱を設ける。これにより、クロストーク現象を低減できる。

【図面の簡単な説明】

【図1】図1(a)から(c)は、それぞれ、実施形態例1の圧電アクチュエータの斜視図、平面図、及び、背面図である。

【図2】圧電材料グリーンシートとその上に塗布した内部電極である共通電極のボタンを示す平面図である。

【図3】圧電材料グリーンシートとその上に塗布した内部電極である信号印加電極のボタンを示す平面図である。

【図4】図4(a)及び(b)は、それぞれ、実施形態例1で形成される積層体の斜視図及び平面図である。

【図5】実施形態例2の圧電アクチュエータの平面図である。

【図6】図6(a)及び(b)は、実施形態例3の圧電アクチュエータの内部電極の駆動柱部ボタンを示す側面断面図であり、図6(a)は共通電極、図6(b)は信号印加電極の駆動柱部を示す。

【図7】実施形態例4の圧電アクチュエータの斜視図である。

【図8】図8(a)及び(b)は、何れも実施形態例5の圧電アクチュエータの内部電極ボタンを示す側面断面図であり、図8(a)は共通電極ボタンを示し、図8(b)は信号印加電極ボタンを示す。

【図9】図9(a)及び(b)は、何れも実施形態例6の圧電アクチュエータの内部電極ボタンを示す側面断面図であり、図9(a)は共通電極ボタンを示し、図9(b)は信号印加電極ボタンを示す。

【図10】実施形態例1から6で、共通電極と信号印加電圧との間に印可する電圧の波形である。

【図11】実施形態例1の圧電アクチュエータをインクジェットヘッドに組み込んだ状態を示す側面断面図である。

【図12】図12(a)及び(b)は、それぞれ、従来の圧電アクチュエータを製造する工程毎の斜視図である。

【符号の説明】

1 圧電アクチュエータ

1a 変位出力面

1c 駆動柱部を含む層群

1d 駆動柱部を含まない層群

1e 積層体

1r 裏面

2 共通電極

3 信号印加電極

4 共通電極を塗布したグリーンシート(シート)

5 信号印加電極を塗布したグリーンシート(シート)

6 駆動柱部

7 電極取り出し部

8 駆動柱

10 垂直方向

11 列設方向

12 溝

13 溝

14 基板

15 共通電極の取り出し部断面

16 信号印加電極の取り出し部断面

21 ノズル

22 圧力室

23 インク流路

24 極端板

26 電極用ボタン

27 電極用ボタン

28 圧電素子プレート

29 駆動部圧電素子

30 固定部圧電素子

31 圧電素子列

32 共通電極

33 個別電極

34 支持部材

36 圧電アクチュエータ

40 圧電アクチュエータ

42 駆動柱

43 溝

44 圧電アクチュエータ

46 a、b 側面

47 a、b 駆動柱部

48 駆動柱

50 圧電アクチュエータ

52 支持柱

56 溝

58 溝

60 圧電アクチュエータ

62 駆動柱

66 駆動柱部

70 圧電アクチュエータ

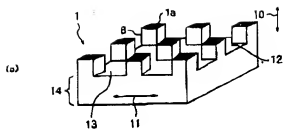
72 駆動柱

74 a、b 側面

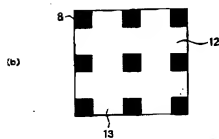
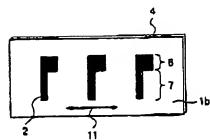
76 a、b 電極取り出し部

78 a、b 外部電極

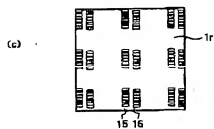
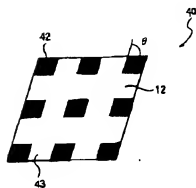
【図1】



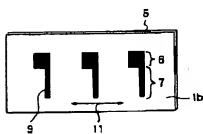
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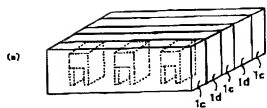
【図5】



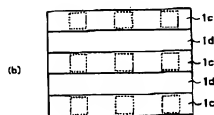
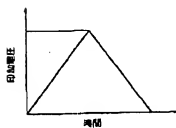
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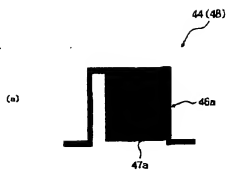
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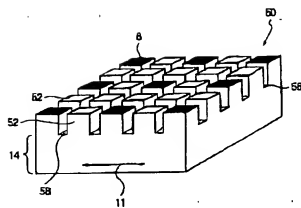
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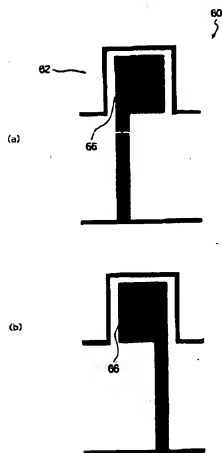
【図 6】



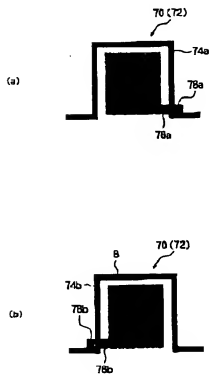
【図 7】



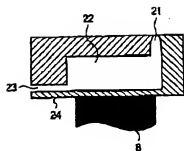
【図 8】



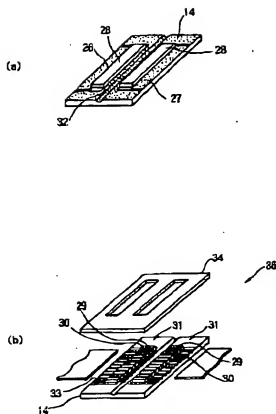
【図 9】



【図11】



【図12】



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 特開 平3-243358 (JP, A)
 特開 平7-166383 (JP, A)
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 特開 平8-25622 (JP, A)
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(58)調査した分野(Int.Cl.¹, DB名)
 B41J 2/045
 B41J 2/055

JAPANESE

[JP,11-227189,A]

AA

CLAIMS DETAILED DESCRIPTION TECHNICAL FIELD PRIOR ART EFFECT OF THE INVENTION
TECHNICAL PROBLEM MEANS DESCRIPTION OF DRAWINGS DRAWINGS

[Translation done.]

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CLAIMS

[Claim(s)]

[Claim 1] It has two or more drive pillars which are arranged at each partition classified by the grid-like slot, respectively, and function as a piezo-electric formula drive. The electrostrictive actuator characterized by having the displacement output screen which a drive pillar consists of laminating electrode structure of the common electrode layer by which the laminating was carried out crosswise [of a slot] by turns through the piezoelectric-material green sheet, and a signal impression electrode layer, and carries out a displacement output to the exterior of the drive pillar neight direction by the piezo-electric transversal effect in a drive pillar upper-limit side.

[Claim 2] It is arranged alternately at each partition classified by the slot of the shape of an abbreviation grid which crosses mutually at an angle of within the limits of 45 degrees or more 90 degrees or less, respectively. It has two or more drive pillars which function as a piezo-electric formula drive. and a drive pillar The electrostrictive actuator characterized by having the displacement output screen which consists of laminating electrode structure of the common electrode layer by which the laminating was carried out crosswise [of a slot] by turns through the piezoelectric-material green sheet, and a signal impression electrode layer, and carries out a displacement output to the exterior of the drive pillar height direction by the piezo-electric transversal effect in a drive pillar upper-limit side.

[Claim 3] The electrostrictive actuator according to claim 1 or 2 characterized by having the electrode takeoff connection which has the edge exposed to the rear face which connects with a common electrode and a signal impression electrode, respectively, and counters the displacement output screen of a drive pillar, respectively.

[Claim 4] The electrostrictive actuator characterized by to have the displacement output screen which it has two or more drive pillars which are arranged on a substrate through a slot and function as a piezo-electric formula drive, respectively, and a drive pillar consists of laminating electrode structure of the common electrode layer by which the laminating was carried out by turns in the direction of the depth of flute through the piezoelectric-material green sheet, and a signal impression electrode layer, and carries out a displacement output outside by the piezo-electric longitudinal effect in the drive pillar upper-limit side of a substrate and an opposite side.

[Claim 5] An electrostrictive actuator given in any 1 term of the claims 1-4 characterized by having a drive pillar and the dummy pillar of outline same height in drive intercolumniation.

[Claim 6] A common electrode and a signal impression electrode are an electrostrictive actuator given in any 1 term of he claims 1-5 characterized by being built in a drive pillar and the front face being worn by piezoelectric-material green-sheet material.

[Claim 7] It is an electrostrictive actuator given in any 1 term of the claims 1-6 which an electrostrictive actuator is an electrostrictive actuator for ink-jet heads, and are characterized by each drive pillar functioning as a drive into which ink is made to flow out of the ink nozzle of an ink-jet head.

[Claim 8] The manufacture method of an electrostrictive actuator according to claim 1 characterized by providing the following The process which applies the electrode paste of a predetermined configuration to the predetermined position of one field of a piezoelectric-material green sheet, forms a common electrode or a signal impression electrode, and forms the laminating electrode soma material which has the internal electrode which comes by turns to carry out two or more sheet laminating of the piezoelectric-material green sheet which subsequently has the piezoelectric-material green sheet which has a common electrode, and a signal impression electrode, and the process which forms the laminating electrode soma material which does not have the internal electrode which comes to carry out two or more sheet laminating of the piezoelectric-material green sheet Subsequently, the process which carries out the laminating of the laminating electrode soma material which has an internal electrode, and the laminating electrode soma material which does not have an internal electrode by turns, pressurizes it, sinters further, and forms a laminating electrode object Subsequently, the process which forms the field which processes the displacement output-screen side which intersects perpendicularly with a sheet side, and has a displacement output screen Furthermore, the process which forms a grid-

http://www4.ipdl.jpo.go.jp/cgi-bin/tran_web_cgi_ejje?u=http%3A%2F%2Fwww6.ipdl.jpo.go.jp%2FToku... 11/4/2003

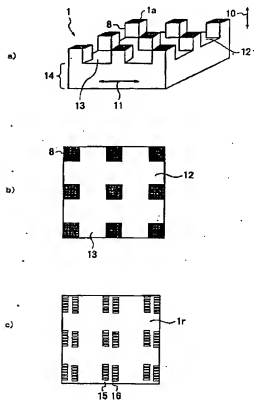
like slot in the field which has a displacement output screen, and forms the drive pillar by which plane configuration was carried out to the shape of the squares of outline regular intervals

[Claim 9] The manufacture method of an electrostrictive actuator according to claim 2 characterized by providing the following process which applies the electrode paste of a predetermined configuration to the predetermined position of one field of a piezoelectric-material green sheet, forms a common electrode or a signal impression electrode, and forms the laminating electrode soma material which has the internal electrode which comes by turns to carry out two or more sheet laminating of the green sheet which subsequently has the green sheet which has a common electrode, and a signal impression electrode, and a piezoelectric-material green sheet -- two or more sheets -- ***** -- the process which forms the laminating electrode soma material which does not have an internal electrode Subsequently, the laminating electrode object formation process which forms the laminating electrode object which shifts in predetermined length one by one, carries out the laminating of the laminating electrode soma material which has an internal electrode, and the laminating electrode soma material which does not have an internal electrode by turns, and pressurizes it, and it comes to sinter further Subsequently, the process which forms the field which processes the displacement output-screen side which intersects perpendicularly with a sheet side, and has a displacement output screen Furthermore, the process which forms the slot of the shape of an abbreviation grid which has the degree of crossed axes angle corresponding to the length shifted at the laminating electrode object formation process in the field which has a displacement output screen

[Claim 10] The manufacture method of the electrostrictive actuator according to claim 9 characterized by the degree of crossed axes angle of a slot being within the limits of 45 to 90 degrees.

[Translation done.]

Drawing selection [Representative drawing] ▾



[Translation done.]

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DETAILED DESCRIPTION

Detailed Description of the Invention]

'0001]

[The technical field to which invention belongs] About an electrostrictive actuator and its manufacture method, especially in more detail, this invention is the the best for an ink-jet method recording device, is formed by high position precision and high accumulation density, and relates to an electrostrictive actuator with possible making it stabilize and drive, and its manufacture method.

'0002]

[Description of the Prior Art] By the printer (henceforth an ink-jet recording device) of an ink-jet formula, the electrostrictive actuator is used for the ink-jet head which injects ink in many cases. The conventional electrostrictive actuator used for an ink-jet head is indicated by JP,8-156272,A. Hereafter, JP,8-156272,A is quoted and the conventional electrostrictive actuator is explained with reference to a drawing. Drawing 12 (a) and (b) are the perspective diagrams for every process which manufactures the conventional electrostrictive actuator, respectively. In order to manufacture the conventional electrostrictive actuator 36, along with the patterns 26 and 27 for electrodes formed on the substrate 14, the laminating type piezoelectric-device plate 28 is joined first (refer to drawing 12 (a)). Subsequently, slit processing of the predetermined pitch which intersects perpendicularly with the longitudinal direction of the piezoelectric-device plate 28 is given to the piezoelectric-device plate 28 and the surface section of a substrate 14, the piezoelectric-device train 31 which consists of two or more laminating type piezoelectric devices (drive pillar) 29 and 30 is formed, and the patterns 26 and 27 for electrodes are divided to the individual electrode (signal impression electrode) 33 corresponding to each laminating type piezoelectric device 29 (refer to drawing 12 (b)).

'0003] The end-face electrode (external electrode) which interconnected the internal electrode every other layer is prepared in the ends side of the piezoelectric devices 29 and 30 of each piezoelectric-device train 31. The external electrode of one end face is connected to the individual electrode 33 which is an internal electrode on a substrate 14 about an other-end side electrode through a conductive material at the common electrode 32 which is an internal electrode on a substrate 14, respectively. Furthermore, the supporter material 34 to which upper surface height becomes almost the same as that of piezoelectric devices 29 and 30 is joined to the circumference of the piezoelectric devices 29 and 30 on a substrate 14. The laminating type piezoelectric devices 29 and 30 have a displacement output screen in the upper-limit side of a substrate and an opposite side, and output the variation rate of the same direction as the direction of a laminating by the piezo-electric longitudinal effect.

'0004]

[Problem(s) to be Solved by the Invention] by the way, with the conventional technology, in order [which processes into a piezoelectric-device plate the slit of the direction which intersects perpendicularly with a longitudinal direction] to form two or more piezoelectric devices of a book especially more, the flat-surface configuration of each piezoelectric device is a rectangle, and serves as arrangement with the same said of the nozzle the ink room allotted up corresponding to it, and for ink regurgitation Moreover, since the piezoelectric device is made to drive using the piezoelectric longitudinal effect, the distance which connects the end-face electrode and electrode pattern of a piezoelectric-device plate by conductive material is needed. Furthermore, an individual electrode is formed in the both ends of the direction which intersects perpendicularly with the piezoelectric-device plate longitudinal direction on a substrate as an electrode pattern corresponding to each piezoelectric-device train. For this reason, if a piezoelectric-device train is put in another way exceeding two trains on one actuator unit, it is difficult to prepare more mostly than two trains, therefore the number of nozzles per unit area could not be raised, but, moreover, there was the 1st problem of a low in productivity. Moreover, since the quality of the materials of a substrate and a piezoelectric device differed, when

processing a slit, there was the 2nd problem which the difference of a mutual coefficient of thermal expansion or processability produces. Furthermore, the distance which pastes all up in case a piezoelectric-device plate and supporter material are joined to a substrate was required, and when having pasted up a piezoelectric-device plate and alignment was carried out to the electrode pattern on a substrate, there was also the 3rd problem that the relative position between each piezoelectric-device plate shifted. It is offering the compact electrostrictive actuator formed by high position precision and high accumulation density by the manufacturing process by which, as for the purpose of this invention, the piezoelectric device's was simplified in the light of the above situations, and its manufacture method.

[0005] Means for Solving the Problem] this invention person -- the result of wholeheartedly examination -- a variation rate -- the electrostrictive actuator which an output screen displaces using the piezo-electric transversal effect -- thinking -- a piezoelectric device -- in-every-direction both directions -- abbreviation -- it is the regular intervals thing done for plane configuration in a grid pattern or alternately, and finds out that a piezoelectric device can be arranged to high accumulation, and this invention person came to complete this invention

[0006] In order to attain the above-mentioned purpose, the electrostrictive actuator of the 1st invention concerning this invention It has two or more drive pillars which are arranged at each partition classified by the grid-like slot, respectively, and function as a piezo-electric formula drive. A drive pillar consists of laminating electrode structure of the common electrode layer by which the laminating was carried out crosswise [of a slot] by turns through the piezoelectric-material green sheet, and a signal impression electrode layer, and it is characterized by having the displacement output screen which carries out a displacement output to the exterior of the drive pillar height direction by the piezo-electric transversal effect in a drive pillar upper-limit side. Two or more drive pillars can be expanded and contracted in the direction of the depth of flute by the piezo-electric transversal effect. Moreover, a drive pillar serves as an electrostrictive actuator from this material, and is formed in one.

[0007] Moreover, the electrostrictive actuator of the 2nd invention concerning this invention It is arranged alternately at each partition classified by the slot of the shape of an abbreviation grid which crosses mutually at an angle of within the limits of 45 degrees or more 90 degrees or less, respectively. It has two or more drive pillars which function as a piezo-electric formula drive. and a drive pillar It consists of laminating electrode structure of the common electrode layer by which the laminating was carried out crosswise [of a slot] by turns through the piezoelectric-material green sheet, and a signal impression electrode layer, and is characterized by having the displacement output screen which carries out a displacement output to the exterior of the drive pillar height direction by the piezo electric transversal effect in a drive pillar upper-limit side.

[0008] In the 1st and the 2nd invention, suitably, it connected with the common electrode and the signal impression electrode inside the electrostrictive actuator, respectively, and has the electrode takeoff connection which has the edge exposed to the rear face which counters the displacement output screen of a drive pillar, respectively. Thereby, it becomes possible to carry out electrical connection of the external power to a common electrode and a signal impression electrode easily. For example, the common electrode and signal impression electrode which are an internal electrode usually consist of a drive pillar section which constitutes a drive pillar, and an electrode takeoff connection which connects with a drive pillar section and arrives even at a rear face, and the configuration of a common electrode and a signal impression electrode is the same configuration, and is arranged about the direction of a laminating in the same position, and by the electrode takeoff connection, it is arranged at a drive pillar section so that it may not lap mutually about the direction of a laminating. Therefore, for every drive pillar, the edge of the electrode takeoff connection of a common electrode and the electrode takeoff connection of a signal impression electrode is arranged at the rear face, respectively, and is exposed at it, and electrical connection can be easily carried out to an external power. Moreover, in applying electrode paste on the surface of a green sheet, and forming an internal electrode, you may form beforehand so that it may fit in the interior of the field where a drive pillar section serves as a drive pillar. And in case a drive pillar is formed, the electrostrictive actuator excellent in endurance is manufactured by processing a grid-like slot and an internal electrode may be settled in a drive pillar.

[0009] Moreover, the electrostrictive actuator of the 3rd invention concerning this invention It has two or more drive pillars which are arranged on a substrate through a slot and function as a piezo-electric formula drive, respectively. A drive pillar consists of laminating electrode structure of the common electrode layer by which the laminating was carried out by turns in the direction of the depth of flute through the piezoelectric-material green sheet, and a signal impression electrode layer, and it is characterized by having the displacement output screen which carries out a displacement output outside by the piezo-electric longitudinal effect in the drive pillar upper-limit side of a substrate and on opposite side.

[0010] In the 1st to 3rd invention, you may have a drive pillar and a dummy pillar in outline same height in drive

columnation, when not making the drive pillar of the next door of a drive pillar (henceforth a drive drive pillar) which is made to drive a drive pillar individually and drives it by this drive, the drive pillar which is not made to drive the places -- large -- it can suppress -- the output of a drive drive pillar -- a variation rate can be used effectively. Moreover, in the 1st to 3rd invention, a common electrode and a signal impression electrode may be built in a drive pillar, and the front face may be worn by piezoelectric-material green-sheet material. The electrostrictive actuator of the 1st to 3rd invention is mainly an electrostrictive actuator for ink-jet heads, and each drive pillar functions as a drive into which ink is made to flow out of the ink nozzle of an ink-jet head. Thereby, the printable electrostrictive actuator for ink-jet recording devices is realizable with high density.

[0011] The manufacture method of the electrostrictive actuator concerning this invention method It is the manufacture method of the electrostrictive actuator the 1st invention, and the electrode paste of a predetermined configuration is applied to the predetermined position of one field of a piezoelectric-material green sheet, and a common electrode or a signal impression electrode is formed. subsequently Come by turns to carry out two or more sheet laminating of the piezoelectric-material green sheet which has the piezoelectric-material green sheet which has a common electrode, and a signal impression electrode. With the process which forms the laminating electrode soma material which has an internal electrode, and the process which forms the laminating electrode soma material which does not have the internal electrode which comes to carry out two or more sheet laminating of the piezoelectric-material green sheet, subsequently With the process which carries out the laminating of the laminating electrode soma material which has an internal electrode, and the laminating electrode soma material which does not have an internal electrode by turns, pressurizes it, sinters further, and forms a laminating electrode object, subsequently the variation rate which intersects perpendicularly with a sheet side -- an output-screen side -- processing it -- a variation rate -- the process which forms the field which has an output screen -- further -- a variation rate -- it is characterized by having the process which forms a grid-like slot in the field which has an output screen, and forms the drive pillar by which plane configuration was changed out to the shape of the squares of outline regular intervals

[0012] A press etc. performs pressurization. As sintering, it calcinates, for example. When a piezoelectric-material green sheet contains a binder in that case, a ** binder process is performed. Moreover, grinding usually performs processing. Since a slot is a grid-like, it is formed in pitches, such as an outline. By formation of a slot, the drive pillar of a high accumulation density by which plane configuration was carried out in a grid pattern can be formed. By the dawn method from the ** 1st, a drive pillar serves as a substrate from this material, and is formed in one. Therefore, the process which joins a piezoelectric-device plate to a substrate becomes unnecessary, generating of the error of the relative position of a drive pillar etc. can be suppressed, and, moreover, productivity improves sharply.

[0013] Moreover, the manufacture method of the electrostrictive actuator of the dawn method from the ** 2nd concerning this invention method It is the manufacture method of the electrostrictive actuator the 2nd invention, and the electrode paste of a predetermined configuration is applied to the predetermined position of one field of a piezoelectric-material green sheet, and a common electrode or a signal impression electrode is formed. subsequently Come by turns to carry out two or more sheet laminating of the green sheet which has the green sheet which has a common electrode, and a signal impression electrode. the process which forms the laminating electrode soma material which has an internal electrode, and a piezoelectric-material green sheet -- two or more sheets -- ***** -- subsequently with the process which forms the laminating electrode soma material which does not have an internal electrode With the laminating electrode object formation process which forms the laminating electrode object which shifts in predetermined length one by one, carries out the laminating of the laminating electrode soma material which has an internal electrode, and the laminating electrode soma material which does not have an internal electrode by turns, and pressurizes it, and it comes to sinter further, subsequently the variation rate which intersects perpendicularly with a sheet side -- an output-screen side -- processing it -- a variation rate -- the process which forms the field which has an output screen -- further -- a variation rate -- it is characterized by having the process which forms the slot of the shape of an abbreviation grid which has the degree of crossed axes angle corresponding to the length shifted at the laminating electrode object formation process in the field which has an output screen By the dawn method from the ** 2nd, the degree of crossed axes angle of a slot is usually within the limits of 45 to 90 degrees.

[0014] [Modiments of the Invention] The example of an operation gestalt is given to below, and the gestalt of operation of the invention is explained to it with reference to an accompanying drawing at concrete and a twist detail. The example of the one example operation gestalt of an operation gestalt is an example of an operation gestalt of the 1st invention. (c) is the perspective diagram of the electrostrictive actuator of this example of an operation gestalt, a plan and rear view from drawing_1 (a), respectively.

[0015] The electrostrictive actuator 1 of this example of an operation gestalt is equipped with two or more drive pillars

which are arranged at each partition classified by the grid-like slot, respectively, and function as a piezo-electric drive. The plan showing the pattern of the common electrode whose drawing 2 is the internal electrode which is formed on it with the piezoelectric-material green sheet, and drawing 3 are the plans showing the pattern of the signal impression electrode which are a piezoelectric-material green sheet and an internal electrode applied on it. The drive pillar 8 consists of laminating electrode structure of the common electrode 2 by which the laminating was carried out by turns [of a slot] by turns through the piezoelectric-material green sheet, and the signal impression electrode 3, and the displacement output-screen (electrostrictive actuator output screen) 1a which carries out a displacement output to the exterior of the drive pillar height direction by the piezo-electric transversal effect in a drive pillar upper-limit side. The common electrode 2 and the signal impression electrode 3 are constituted from a drive pillar section 6 which constitutes a drive pillar, and an electrode takeoff connection 7 which connects with the drive pillar section 6 and reaches even rear-face 1r (refer to drawing 1 (c)) of an electrostrictive actuator 1 by each. Moreover, the common electrode 2 and the signal impression electrode 3 are formed so that it may be arranged in the position with which the drive pillar section 6 is the same position about the direction of a laminating, and the electrode takeoff connection 7 does not lap mutually about the direction of a laminating, respectively. In rear-face 1r, the edge of the electrode takeoff connection of a common electrode and the electrode takeoff connection of a signal impression electrode arranges and is exposed to a single tier for every drive pillar, respectively (refer to drawing 1 (c)).

[6] In this example of an operation gestalt, although the number of the common electrodes 2 and the signal impression electrodes 3 which are applied to each sheet is three, respectively, according to the number of requests of the drive pillar 8, you may make [more / still] them. Moreover, although what consists of PZT system ceramics which is a piezoelectric material as a piezoelectric-material green sheet (only henceforth a green sheet), and an organic binder are used, you may use the common ferroelectric as a piezoelectric material etc. Moreover, although the green sheet is manufactured using the doctor blade method and thickness was set to about 30 micrometers, it is possible to consider as the thickness according to the amount of displacement of a request of an electrostrictive actuator 1.

[7] Hereafter, the manufacture method of an electrostrictive actuator is explained. First, the laminating of the sheet which applied the common electrode 2, and the sheet 5 which applied the signal impression electrode 3 was carried out by turns so that the drive pillar section 6 of each electrode pattern might lap mutually, and so that the electrode takeoff connection 7 might not lap mutually in the common electrode 2 and the signal impression electrode 3 (this thing which carried out the laminating is hereafter called "group containing a drive pillar section"). The group containing a drive pillar section consists of 20 layers. Moreover, two or more sheet laminating of the sheet which does not apply an electrode was carried out separately (this thing that carried out the laminating is hereafter called "group which does not contain a drive pillar section"). The group which does not contain a drive pillar section also consists of 20 layers. in addition -- although the common electrode 2 and the signal impression electrode 3 on a green sheet were formed by applying a silver palladium paste (screen-stencil) -- other conductors -- you may form by vacuum evaporation etc. forming a metal.

[8] Subsequently, the laminating of the 1d of the groups which do not contain a drive pillar section was further carried out to group 1c containing a drive pillar section by turns, and layered product 1e which has 1d of two groups which do not contain three bodies and a drive pillar section for group 1c containing a drive pillar section was formed. drawing 4 (a) and (b) are the perspective diagrams and plans of layered product 1e, respectively. A dashed line shows the outer frame of the common electrode 2 built in and the signal impression electrode 3 by drawing 4. In addition, in drawing 4 (a), since it is easy, the dashed line is drawn only on the thing of most this side among group 1c containing a drive pillar section. As a result of carrying out a laminating by turns, as shown in drawing 4 (a) and (b), the portion which forms the drive pillar 8 was arranged by three trains, respectively in the direction which intersects perpendicularly in the successive installation direction 11 of internal electrodes 2 and 3, i.e., a direction parallel to each green sheet, and the successive installation direction 11. In addition, it is also possible to carry out the laminating of more groups according to the desired array of the drive pillar 8.

[9] Subsequently, with a heat press etc., the above-mentioned layered product 1e was stuck by pressure, and it was pressed. Since a lot of organic binders were contained inside layered product 1e, further, ** binder distance was performed, and it calcinated at 1100 degrees C continuously. Subsequently, the dicing saw cut in the desired size as a portion of an electrostrictive actuator at the layered product after baking. At that time, in consideration of positioning a layered product at the time of recessing for separating each drive pillar 8 and making it become independent, it was processed so that the edge of the common electrode 2 and the signal impression electrode 3 might be exposed to the displacement output-screen 1a. Furthermore, appearance processing which the edge of the electrode takeoff connection 7c crosses was performed from the rear-face side of a layered product, and the terminal which impresses voltage to each drive pillar 8 was formed in rear-face 1r.

[0020] Then, the dicing saw performed recessing and the drive pillar 8 which has the drive pillar section 6 was formed so that it might explain below. First, two or more slots 12 which have the same width of face as 1d of groups which do not contain a drive pillar section were formed between the groups which contain a drive pillar section in the successive installation direction 11. The slot 12 was formed by putting in slitting with a depth of 1mm from the upper surface. Then, the slot 13 which has the same width of face as the interval between drive pillar sections was processed in the direction of an internal-electrode laminating which intersects perpendicularly with a slot 12, and two or more drive pillars 8 were formed in it (refer to drawing 1 (a) and (b)).

[0021] The drive pillars 8 are an electrostrictive actuator 1 and this material, and one was consisted of by the above distance, and the electrostrictive actuator by which plane configuration of the drive pillar 8 was carried out to the shape of a matrix was manufactured. In addition, although each of each drive pillar pitches of the direction where each width of face [each of] of 0.718mm and the drive pillar 8 in every direction is 0.3mm, and the successive installation direction 11 of internal electrodes 2 and 3 and it, and the width of face of slots 12 and 13 cross at right angles is 1.018mm, these values can be changed according to the request pitch of a drive pillar etc.

[0022] Subsequently, external electrode connection for applying applied voltage to each drive pillar 8 was made as follows. In rear-face 1r, the takeoff-connection cross section 15 of the common electrode 2 and the takeoff-connection cross section 16 of the signal impression electrode 3 corresponding to each drive pillar 8 were exposed, respectively, applied the silver paste (not shown) to these, and formed the external electrode. Furthermore, the FPC cable (not shown) which has the possible pattern of carrying out voltage impression alternatively between the common electrode 2 of each drive pillar 8 and the signal impression electrode 3 was connected to the external electrode. Consequently, each drive pillar 8 can be driven individually. In addition, the method of the above [an external electrode] -- replacing with -- a conductor -- metalized vacuum evaporation and a conductor -- you may form by performing printing of a paste etc.

[0023] Hereafter, operation of the electrostrictive actuator 1 manufactured in this example of an operation gestalt is explained. Voltage is impressed through the FPC cable linked to rear-face 1r between the common electrode 2 of each drive pillar 8, and the signal impression electrode 3. Thereby, the potential difference arises through the electrode takeoff connection 7 between the drive pillar section 6 of the common electrode 2, and the drive pillar section 6 of the signal impression electrode 3, and the variation rate of a perpendicular direction 10 is outputted to displacement output screen 1a by the piezo-electric transversal effect.

[0024] In addition, an electrostrictive actuator 1 replaces with the common electrode 2 and the signal impression electrode 3. It has the common electrode and signal impression electrode by which the laminating was carried out by turns in the direction of the depth of flute through the piezoelectric-material green sheet. Even if it is the structure of having the displacement output screen (electrostrictive actuator output screen) which carries out a displacement output to the exterior of the drive pillar height direction by the piezo-electric longitudinal effect in a drive pillar upper-limit section, like this example of an operation gestalt, it is compact and it is possible to carry out a variation rate for every drive pillar.

[0025] As a result of impressing the voltage of a wave as shown in the FPC cable connected to the example of experiment 1 electrostrictive actuator 1 which performed the check of an electrostrictive actuator of operation at drawing 10, the variation rate of about a maximum of 0.3 micrometers has been outputted. the result which conducted the same drive experiment also to other drive pillars -- an output equivalent with all drive pillars -- a variation rate -- the property was acquired Furthermore, as shown in drawing 11, it attached by including an electrostrictive actuator 1 in the ink-jet head which has a nozzle 21, the pressure room 22, the ink passage 23, and a diaphragm 24. Subsequently, as a result of impressing the voltage of the wave shown in drawing 10 and performing the regurgitation evaluation examination of an ink drop, it checked that the regurgitation of the ink drop could be stably carried out from all the nozzles 21.

[0026] The example of the two example operation gestalt of an operation gestalt is an example of an operation gestalt of the electrostrictive actuator of the 2nd invention, and its manufacture method. Drawing 5 is the plan of the electrostrictive actuator of this example of an operation gestalt. The electrostrictive actuator 40 of this example of an operation gestalt is the same composition as an electrostrictive actuator 1 except for plane configuration of the drive pillar being alternately carried out to the shape of a matrix which intersects perpendicularly in all directions compared with the electrostrictive actuator 1 of the example 1 of an operation gestalt by which plane configuration is carried out. The drive pillar 42 of an electrostrictive actuator 40 is arranged alternately at each partition classified by the slot of the shape of an abbreviation grid which crosses mutually with the degree of crossed axes angle of $\theta = 85$ degrees, respectively, and functions as a piezo-electric formula drive.

[0027] In order to have manufactured the electrostrictive actuator 40 in this example of an operation gestalt, when carrying out the laminating of the group containing a drive pillar section, and the group which does not contain a drive

pillar section by turns compared with the example 1 of an operation gestalt using the sheet 4 and sheet 5 which were used in the example 1 of an operation gestalt, group 1c containing a drive pillar section carried out and changed the laminating into the state where only the same predetermined length moved in the successive installation direction 11 by one by one. Predetermined length is the length corresponding to the degree theta of crossed axes angle. Then, ** binder distance, baking, and appearance processing were performed like the example 1 of an operation gestalt.

[0028] Then, the dicing saw performed recessing explained below and the drive pillar 42 containing the drive pillar section 6 of the internal electrode (the common electrode 2 and signal impression electrode 3) exposed to the upper surface was formed. First, the slot 12 was formed like the example 1 of an operation gestalt. Subsequently, the slot 12 and the slot 43 which crosses at 85 degrees were formed. The drive pillars 42 were an electrostrictive actuator 40 and drive pillar, and same material was consisted of by the above distance and the electrostrictive actuator 40 by which plane configuration was moreover carried out alternately was manufactured.

[0029] As a result of conducting the same drive experiment as the example 1 of example of experiment 2 experiment which performed the check of an electrostrictive actuator of operation, it checked outputting the variation rate all whose drive pillars are about 0.3 micrometers. Furthermore, when it included in the ink-jet head which showed the actuator manufactured in this example of an operation form to drawing 11 and the **** evaluation examination was performed, the ink drop has been stabilized and ****(ed) from all the nozzles 21.

[0030] The example of the three example operation gestalt of an operation gestalt is an example of an operation gestalt of the electrostrictive actuator which can perform electrical connection to the internal electrode of an external power source by rear-face 1r of an actuator output screen but by displacement output-screen 1a, and its manufacture method. Each of drawing 6 (a) and (b) is the side cross sections showing the internal-electrode pattern of the electrostrictive actuator 44 of this example of an operation gestalt, drawing 6 (a) shows a common electrode pattern, and drawing 6 (b) shows a signal impression electrode pattern. The electrostrictive actuator 44 is equipped with the drive pillar 48. The drive pillar 48 is formed in the same position with the same composition as the drive pillar 8 except for the edge of the common electrode 2 and the signal impression electrode 3 being exposed to side 46a which counter mutually, and b, respectively.

[0031] In order to have manufactured the electrostrictive actuator 44, it formed by applying the common electrode and signal impression electrode which are the example 1 of an operation gestalt, or 2, and have drive pillar section 47a and 47b, respectively instead of applying the common electrode 2 and the signal impression electrode 3 on a green sheet (green-stencil). Then, the drive pillar 48 which exposed the edge of drive pillar section 47a of a common electrode and drive pillar section 47b of a signal impression electrode, respectively was formed in side 46a which counter mutually, and 46b, respectively by forming a layered product and performing appearance processing and recessing like the example 1 of an operation gestalt, or 2. Furthermore, the electric wiring which applies a silver paste (not shown) to side 46a and 46b as an external electrode on the whole surface, then impresses voltage from an external power was connected to this external electrode.

[0032] Since the electrostrictive actuator 44 of this example of an operation gestalt does not need to form the electrode connection 7 connected to rear-face 1r of an actuator output screen from the drive pillar section 6 like the examples 1 and 2 of an operation gestalt, the amount of internal-electrode material or the piezoelectric material used can be reduced, and the low electrostrictive actuator of a manufacturing cost is realized.

[0033] Example of operation gestalt 4 drawing 7 is the perspective diagram of the electrostrictive actuator of this example of an operation gestalt. The electrostrictive actuator 50 of this example of an operation gestalt has the support pillar 52 which consists only of a piezoelectric-material green sheet in which are a drive pillar and an outline same size and the laminating was carried out to drive intercolumniation by grid-like recessing compared with the electrostrictive actuator of the example 1 of an operation gestalt by which only a drive pillar is formed in the layered product upper part as a dummy pillar. The support pillar 52 does not have the common electrode 2 and the signal impression electrode 3 which are an internal electrode, but consists of only piezoelectric-material green sheets by which the laminating was carried out.

[0034] The manufacture method of an electrostrictive actuator 50 is explained below. In this example of an operation gestalt, layered product 1e was first formed like the example 1 of an operation gestalt. Subsequently, it was the slot which forms the drive pillar 8 and the support pillar 52, and it was parallel to the successive installation direction 11, and the slot 56 formed between 1d of groups which do not contain group 1c containing a drive pillar section and a drive pillar section was processed. Then, the slot 58 was processed between the drive pillar 8 and the support pillar 52 towards intersecting perpendicularly with a slot 56. Although width of face of the drive pillar 8 and the support pillar 52 was set to 1.018mm in this example of an operation gestalt, respectively in 0.3mm and the direction which intersects perpendicularly the pitch of 0.209mm and the drive pillar 8 in the successive installation direction 11 and the

successive installation direction of an internal electrode in the width of face of slots 56 and 58, these values can be changed according to the request pitch of a drive pillar etc.

[0035] The electrostrictive actuator 50 manufactured by the example of the three example operation gestalt of an experiment which performed the check of an electrostrictive actuator of operation was applied as an ink-jet head like the example 1 of an experiment, and the experiment which compares about the regurgitation of the ink drop in the case where there is nothing with the case where there is a support pillar 52 was conducted. Consequently, deformation of other parts suppresses by having had the support pillar 52 further -- having -- the output of the drive pillar 8 -- the variation rate could be used effectively and the degree of a cross talk phenomenon has been reduced namely, the output which the regurgitation takes -- it was checked that can mitigate a variation rate and dispersion in the regurgitation property of each nozzle mitigates

[0036] The example of the five example operation gestalt of an operation gestalt is an example of an operation gestalt of the electrostrictive actuator of the structure which the drive pillar section of an internal electrode does not expose compared with the example 1 of an operation gestalt. Each of drawing 8 (a) and (b) is the side cross sections showing the internal-electrode pattern of the electrostrictive actuator 60 of this example of an operation gestalt, drawing 8 (a) shows a common electrode pattern, and drawing 8 (b) shows a signal impression electrode pattern. The electrostrictive actuator 60 is the same as the electrostrictive actuator 1 of the example 1 of an operation gestalt except for the common electrode and signal impression electrode which are an internal electrode being built in the drive pillar 62 of an electrostrictive actuator 60, and the front face being worn by piezoelectric-material green-sheet material.

[0037] In order to manufacture an electrostrictive actuator 60, in case a slot is processed, except for processing it so that the edge of the drive pillar section 66 of an internal electrode may not be exposed to the outside of the drive pillar 62, it is the same as the example 1 of an operation gestalt.

[0038] In this example of an operation gestalt, since the drive pillar section 66 is formed so that it may fit in the interior of the drive pillar 62, and an internal electrode is not exposed to the outside of the drive pillar 62 at the process which applies an internal electrode on a green sheet, there is an effect which can suppress the short circuit between each electrode layer.

[0039] The experiment which compares the endurance ability when not exposing with the case where the drive pillar section 66 of an internal electrode is exposed, using the example electrostrictive actuator 60 of an experiment which performed the performance check of an electrostrictive actuator was conducted. Consequently, it was checked by not exposing the drive pillar section 66 that endurance can be improved.

[0040] Although the depth of flute of the shape of a grid and an abbreviation grid was processed according to the soffit of the drive pillar section 66 of an internal electrode in the example 5 of the example operation gestalt of an alteration of the example 5 of an operation gestalt as shown in drawing 8, the 1st electrostrictive actuator (not shown) of this example of an alteration is an electrostrictive actuator which comes to form a grid-like slot rather than the soffit of the drive pillar section 66 deeply relatively. In the 1st electrostrictive actuator, the stress concentration in the groove bottom edge section circumference was eased, and the effect which can improve the endurance of an electrostrictive actuator 60 further was acquired. Moreover, the 2nd electrostrictive actuator (not shown) of this example of an alteration is an electrostrictive actuator with the soffit position of the drive pillar section 66 deeper than the bottom of a grid-like slot. The 2nd electrostrictive actuator -- the drive pillar of the same height -- comparing -- an output -- the effect which can improve a variation rate was acquired. Furthermore, although the drive pillar was considered as the composition which carries out plane configuration of nine of every direction 3x3 in the example 5 of an operation gestalt, the electrostrictive actuator which has further many drive pillars 62 compared with an electrostrictive actuator 60 was able to be formed by increasing the number of electrode patterns of the sheet of one sheet, or increasing the number of laminations of the group containing a drive pillar section, and the group which does not contain a drive pillar section according to a desired array. In addition, it checked that the same effect as this example of an alteration was acquired also in the examples 1-4 of an operation gestalt.

[0041] Each of example of operation gestalt 6 drawing 9 (a) and (b) is the side cross sections showing the internal-electrode pattern of the electrostrictive actuator of this example of an operation gestalt, drawing 9 (a) shows a common electrode pattern, and drawing 9 (b) shows a signal impression electrode pattern. The electrostrictive actuator 70 of this example of an operation gestalt is the same composition as the electrostrictive actuator 60 of the example 5 of an operation gestalt except for an internal electrode replacing electrode takeoff-connection 76a and b with the electrode takeoff connection 7, and having them. Electrode takeoff-connection 76a and b have exposed the edge to side 74a and b with the drive pillar 72 of an electrostrictive actuator 70 counters. In this example of an operation gestalt, after manufacturing an electrostrictive actuator 70, side 74a, external electrode 78a which come to apply a silver paste to the internal-electrode edge exposed to b, and b were formed. By this example of an operation gestalt, the same effect as the

Example 5 of an operation gestalt was able to be done so.

[Fig. 2]

[Effect of the Invention] As explained above, according to the electrostrictive actuator concerning the 1st invention of the invention, it has two or more drive pillars which are arranged at each partition classified by the grid-like slot, respectively, and function as a piezo-electric formula drive, and a displacement output is carried out to the exterior of the drive pillar height direction by the piezo-electric transversal effect. Thereby, since it is the same quality of the material as an electrostrictive actuator and two or more drive pillars can be prepared in an electrostrictive actuator and one, it becomes reducible [the improvement in the position precision of a drive pillar, and a manufacturing process]. Moreover, since the electric end-connection section of the internal electrode which the plane configuration of the drive pillar can be carried out in the shape of a matrix, and constitutes a drive pillar can be performed with the actuator rear surface, the compact electrostrictive actuator by which the drive pillar has been arranged by high accumulation density is realized. An effect with the same said also of the 2nd and the 3rd invention can be done so. The dummy pillar which consists only of a piezoelectric-material green sheet by which are a drive pillar and outline same height and the manufacturing was suitably carried out to drive intercolumniation is prepared. Thereby, a cross talk phenomenon can be prevented.

[Translation done.]

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

- [Drawing 1] (c) is the perspective diagram of the electrostrictive actuator of the example 1 of an operation gestalt, a plan, and rear view from drawing 1 (a), respectively.
- [Drawing 2] It is the plan showing the pattern of the common electrode which are a piezoelectric-material green sheet and an internal electrode applied on it.
- [Drawing 3] It is the plan showing the pattern of the signal impression electrode which are a piezoelectric-material green sheet and an internal electrode applied on it.
- [Drawing 4] Drawing 4 (a) and (b) are the perspective diagrams and plans of a layered product which are formed in the example 1 of an operation form, respectively.
- [Drawing 5] It is the plan of the electrostrictive actuator of the example 2 of an operation form.
- [Drawing 6] Drawing 6 (a) and (b) are the side cross sections showing the drive pillar section pattern of the internal electrode of the electrostrictive actuator of the example 3 of an operation form, drawing 6 (a) shows a common electrode and drawing 6 (b) shows the drive pillar section of a signal impression electrode.
- [Drawing 7] It is the perspective diagram of the electrostrictive actuator of the example 4 of an operation gestalt.
- [Drawing 8] Each of drawing 8 (a) and (b) is the side cross sections showing the internal-electrode pattern of the electrostrictive actuator of the example 5 of an operation gestalt, drawing 8 (a) shows a common electrode pattern, and drawing 8 (b) shows a signal impression electrode pattern.
- [Drawing 9] Each of drawing 9 (a) and (b) is the side cross sections showing the internal-electrode pattern of the electrostrictive actuator of the example 6 of an operation gestalt, drawing 9 (a) shows a common electrode pattern, and drawing 9 (b) shows a signal impression electrode pattern.
- [Drawing 10] It is the examples 1-6 of an operation form, and is the wave of the voltage which carries out a seal of the seal between a common electrode and signal applied voltage.
- [Drawing 11] It is the side cross section showing the state where the electrostrictive actuator of the example 1 of an operation form was included in the ink-jet head.
- [Drawing 12] Drawing 12 (a) and (b) are the perspective diagrams for every process which manufactures the operational electrostrictive actuator, respectively.

[Description of Notations]

- 1 Electrostrictive Actuator
- 1 Displacement output screen
- 1 The group containing a drive pillar section
- 1 The group which does not contain a drive pillar section
- 1 Layered product
- 1 Rear face
- 2 Common Electrode
- 2 Signal Impression Electrode
- 4 Green Sheet Which Applied Common Electrode (Sheet)
- 5 Green Sheet Which Applied Signal Impression Electrode (Sheet)
- 6 Drive Pillar Section
- 6 Electrode Takeoff Connection
- 1 Drive Pillar
- 1 Perpendicular Direction
- 1 Successive Installation Direction

1 Not
 1 At
 1 Substrate
 1 Takeoff-Connection Cross Section of Common Electrode
 1 Takeoff-Connection Cross Section of Signal Impression Electrode
 1 Nozzle
 2 Pressure Room
 1 Ink Passage
 1 Diaphragm
 1 Pattern for Electrodes
 1 Pattern for Electrodes
 2 Piezoelectric-Device Plate
 2 Mechanical-Component Piezoelectric Device
 2 Hard Part Piezoelectric Device
 1 Piezoelectric-Device Train
 1 Common Electrode
 1 Individual Electrode
 1 Supporter Material
 1 Electrostrictive Actuator
 1 Electrostrictive Actuator
 1 Drive Pillar
 4 C
 4 Electrostrictive Actuator
 2 Side
 1 Drive pillar section
 1 Drive Pillar
 1 Electrostrictive Actuator
 1 Support Pillar
 1 Not
 1 Not
 1 Electrostrictive Actuator
 1 Drive Pillar
 1 Drive Pillar Section
 1 Electrostrictive Actuator
 1 Drive Pillar
 1 Side
 1 Electrode takeoff connection
 1 External electrode

1 [. tion done.]

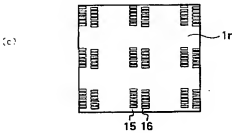
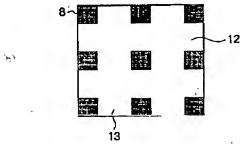
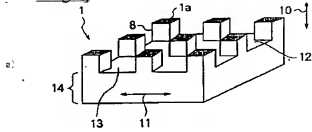
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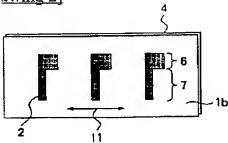
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DRAWINGS

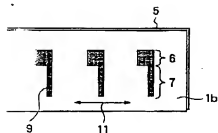
[Drawing 1]



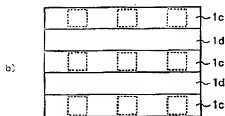
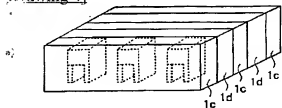
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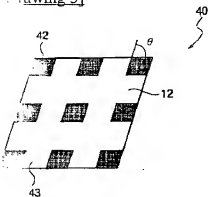
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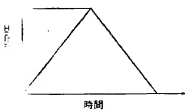
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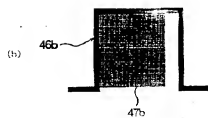
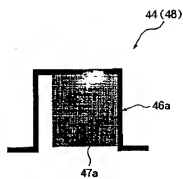
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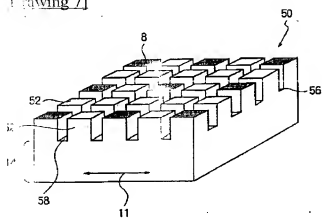
Drawing 10]



Drawing 6]



Drawing 7]

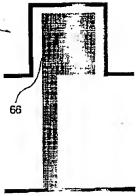


Drawing 8]

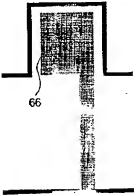
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62

62



a)



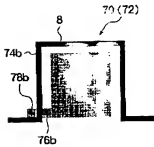
b)

Drawing 91

70 (72)

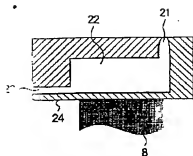


(c)

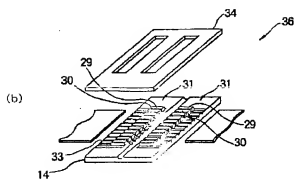
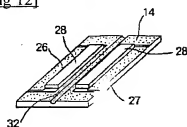


(d)

Drawing 111



[Drawing 12]



[Translation done.]